

# **Central Systems**

## **Program Mission**

As part of the President's Coal Research Initiative, the overall goal of the Central Systems Program is to provide the critical research that can dramatically reduce coal power plant emissions and significantly improve efficiency to reduce carbon emissions. The National Energy Policy recommends that the Department continue to develop advanced clean coal technology with a goal of deploying high efficiency coal power plants achieving zero emissions. Further, the President's Clear Skies Initiative is supported by the development of advanced emission control technology and related byproducts as part of the research portfolio under Central Systems. The President's Climate Change Initiative over the longer term is supported through technology for advanced power plants that can nearly double the average efficiency of today's fleet of coal power plants, thereby significantly reducing carbon emissions.

The growing national economy relies increasingly on electricity supply that is secure, affordable, and reliable. This is especially true in the face of concerns over national energy security as well as electricity generation market restructuring. In addition, compliance with more stringent environmental regulations requires reduced emissions from electric power plants. Further, new technology is needed to develop much cleaner and more efficient plants to replace and augment an aging power generation infrastructure. Electricity demand from both natural gas and coal is projected to increase significantly through the year 2015 to meet increased energy demand in the U.S. (Annual Energy Outlook, 2002).

The program elements for Central Systems include technology developed for existing plants, advanced systems, and Vision 21 are as follows:

- **Innovations for Existing Plants (IEP)** - The IEP program element has a near-to-mid term focus on improving overall power plant efficiency (thereby reducing carbon emission) and developing advanced cost-effective environmental control technologies for retrofitting to existing powerplants and other coal technologies such as integrated gasification combine cycle (IGCC). These advanced systems and technologies have direct application to new plants as well. The research is also directed at the environmentally sound use and disposal of coal byproducts and at novel systems and technologies to minimize the impact of electricity production on water availability and quality. The IEP program directly supports the goals and objectives of the President's February 14, 2002 Clear Skies Initiative that calls for substantial reductions in mercury, NO<sub>x</sub>, and SO<sub>2</sub> emissions from power plants. Results of this advanced research are used by those who develop, design, manufacture and operate both existing and advanced systems across the entire spectrum of coal utilization technologies not only to improve efficiencies, but also to improve environmental performance. This program's crosscutting efforts address the cost-effective removal of pollutant causing contaminants from fossil fueled systems while maximizing the efficient recycling of all by products.
- **Integrated Gasification Combined Cycle (IGCC)** - The IGCC program supports both the President's Clear Skies Initiative and climate change goals by enhancing the thermal efficiency of converting coal to electricity, providing the potential for over 50% reduction in CO<sub>2</sub> compared to today's technologies, and through its performance goals of achieving near-zero emissions of SO<sub>2</sub>, NO<sub>x</sub>,

mercury, and other pollutants. The IGCC program conducts research that fosters the development and deployment of fuel-flexible gasification-based processes for converting carbon-based feedstocks to electricity, steam, and a broad range of chemicals, including ultra-clean transportation fuels like hydrogen. In order to achieve the full potential of IGCC, significant advances must be made to reduce the capital and operating and maintenance costs and to improve both the reliability and the overall system availability. In FY 2004, emphasis will be placed on gas stream purification to meet quality requirements for use with fuel cells and conversion processes; advanced gasification concepts for multi-fuel capability; development of technologies with multi-fuel capabilities; enhanced process efficiency; and reduced costs for producing oxygen and hydrogen and reducing greenhouse emissions. The successful accomplishment of these activities will enhance the commercialization prospects of advanced IGCC technologies for the production of electricity for use by utilities, independent power producers, and other industrial stakeholders.

- **Pressurized Fluidized Bed (PFB)** - This program was redirected in prior years to support advanced combustion hybrid concepts for Vision 21. In FY 2004, specific technologies from this category are being folded into the Gasification activity so to enhance the integration of hybrid combustion/gasification concepts, including support for the test activity at the Wilsonville Power Systems Development Facility (PSDF).
- **Turbines** - The High Efficiency Engines and Turbines (HEET) program builds on technology created in the Advanced Turbines Systems (ATS) Program. The HEET Program is focused on key technologies needed to enable the development of advanced turbines and engine modules for fuel flexible energy plants. Developing advanced turbines with fuel flexibility is critical as many of the advanced, coal-fired power generation technologies currently being developed or demonstrated will incorporate modified gas turbine systems. The HEET Program is an investment in secure U.S. electric power production which is clean and efficient and is fuel-flexible, highly reliable, maintainable, durable, affordable.

During FY 2003, DOE will have completed the concept studies to run ATS and other machines on coal syngas, as well as ATS machines in coal and natural gas based integrated hybrid power modules, demonstrated the Clean Energy Systems 10MW low-emission steam generator, demonstrated an integrated sensor suite for real-time monitoring of an advanced turbine's operational performance, and demonstrated in-situ single crystal blade welding and repair techniques. In FY 2004, the R&D will focus on combustor performance and design using coal derived syngas, models/simulation tools for low-emission combustion systems, and tools that can predict reliability, availability, and maintainability.

**Vision 21** is an integration of advanced power systems R&D. This integrated development effort will lead to the deployment of a family of plants that converts a combination of feedstocks (e.g., coal, natural gas, biomass, and opportunity fuels such as, petroleum coke or heavy oil resid (refinery wastes)) to electricity, heat (e.g., steam), and a suite of high-value products that may include synthesis gas, hydrogen, chemicals, and saleable by-products (e.g., sulfur and ash or slag). Research and development continues on key enabling technologies, supporting R&D, and systems analyses, simulations and integration through the government/industry/laboratory/university cost-shared partnership based on the gasification route in the Vision 21 technology roadmap. Alternate technology paths for Vision 21 will be

studied at the concept level in FY 2004.

## Program Specific Performance Goals

**ER 4-1:** Innovations for Existing Plants: Support the President's Clear Skies Initiative by having technologies ready for commercial demonstration by 2005 with the potential to reduce: Mercury by 50 - 70 percent at 70 percent of today's cost of \$50,000-\$70,000/lb of mercury; NO<sub>x</sub> to less than 0.15 lb/mmBtu at ¾ cost of SCR, currently \$80-\$100/Kw; PM2.5 by 99.99 percent FOR LESS THAN \$50-\$70/Kw; and acid gases by 95 percent. By 2010, test technologies for advanced cooling, mercury reduction by 90 percent at 70 percent of today's cost of \$50,000-\$70,000/lb of mercury; and 66 percent increase in byproducts utilization.

**Performance Indicator:** Number of tests of technologies that offer reductions in emissions and/or costs of mercury, NO<sub>x</sub>, particulate, and acid gasses.

## Annual Performance Targets and Results

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
<b>Innovations for Existing Plants:</b>		
Complete Phase I report characterizing concentration and composition for ambient PM2.5 emissions as input to the EPA PM2.5 National Ambient Air Quality Standards (NAAQS) review. This data will identify the impact of emission sources on air quality.	<p>Initiate projects for developing technologies to address emerging electric utility/water issues and combustion byproducts utilization and disposal.</p> <p>Complete preliminary field testing of alternative mercury control technologies representing two approaches for achieving 50% or greater removal.</p> <p>Complete fine particulate monitoring in the Upper Ohio River Valley region; complete field testing of alternative particulate matter collection technologies representing at least two approaches for achieving 99.99% removal; initiate research on PM<sub>2.5</sub> and</p>	<p>Complete a total of three initial tests of the leachability and volatilization of mercury from coal byproducts, of advanced separation techniques for combustion ash, and of advanced approaches for cooling. The coal byproducts leachability tests will determine what if any mercury leachability issues exist for the byproducts tested, which is critical to allow the safe use and disposal of the byproducts. Advanced cooling technologies will be identified to determine low costs approaches to comply with potential water restrictions.</p> <p>Complete six initial pilot-scale tests for development of performance data on an advanced concept potentially</p>

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	<p>mercury transport and deposition.</p> <p>Initiate developmental testing of SCR catalysts for reducing NO<sub>x</sub> emissions from alternatively fueled boilers.</p>	<p>capable of 90% mercury capture. This information will be used in identifying further development needs and opportunities as a potential technological option to achieve anticipated Federal regulations for mercury emission control.</p> <p>Complete development and dissemination of data on regional fine particulate and fine particulate data analysis methods. This would determine the amount and type of emissions from coal-fired power plants, and inform decision-making on regulatory initiatives by Federal and state agencies and the R&amp;D requirement for new control technologies.</p> <p>Complete pilot scale testing on advanced ultra-low-nitrogen oxide burner systems that achieve .15 lbs/mmBTU NO<sub>x</sub>. Successful completion of this pilot scale testing clears the way for commercial scale demonstration of this low cost, low NO<sub>x</sub> emissions technology.</p>

**ER 4-2:** Advanced Systems: By 2008, develop advanced power systems capable of achieving 50% thermal efficiency at a capital cost of \$1000/kW or less for a coal-based plant. (same as ER 4-2) .

**Performance Indicator:** Number of tests of critical component technologies needed to achieve advanced power systems goal of 50 percent thermal efficiency and \$1,000/kW.

## Annual Performance Targets and Results

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Complete initial tests of the IGCC transport gasifier to confirm the feasibility of the technology to significantly improve reliability, cost effectiveness, and efficiency for producing electricity and other products.	<p>Establish a 1-5 tpd facility capable of determining engineering feasibility, defining technical performance, and establishing operating costs for oxygen separation using membrane technology.</p> <p>Complete initial laboratory-scale performance testing of hydrogen separation membranes using simulated gas streams.</p> <p>Complete initial laboratory tests to determine performance capabilities of sorbents, sieves, and membranes for removing mercury, sulfur, nitrogen, and CO<sub>2</sub> from gas streams.</p> <p>Conduct gasification support tests on leachability of gasifier residues, improved refractories, and oxygen-blown gasification of alternative fossil fuel feedstocks, and develop a simulator for a Vision 21 plant.</p> <p>Develop technical and cost information sufficient for DOE decision-making on the viability of proceeding with plans for construction of a co-production plant.</p> <p>Complete conceptual studies to assess ATS and other machines for operation on coal syngas, as well as, ATS machines in coal and natural gas based integrated hybrid power modules,</p>	<p>Complete an initial pilot-scale test of an oxygen transport membrane system that has the potential to increase the efficiency and reduce the cost of oxygen-blown integrated gasification combined-cycle systems to 50% efficiencies at \$1000 kWe by 2008.</p> <p>Complete initial screening of materials and fabrication techniques that will be used in a sub-scale module that will be scaleable to a Vision 21 plan, and develop of bench-scale exposure data required to identify and select hydrogen membranes capable of supporting integrated gasification combined-cycle plant operating conditions that will achieve 60% efficiencies at \$850 to \$900 /kWe by 2015, while producing a concentrated, high-pressure stream of carbon dioxide for sequestration.</p> <p>Complete fabrication of an ammonia and mercury removal test module to be integrated with a pilot-scale gasifier to be available for testing in FY 2005.</p> <p>Complete development of preliminary performance data for a hybrid gasification system. These data will provide information needed to establish feasibility of a concept design that can achieve 50% efficiencies at \$1000/kWe by</p>

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	<p>complete demonstration of a low-emission steam generator, demonstrated an integrated sensor suite for real-time monitoring of an advanced turbine's operational performance, and demonstrated in-situ single crystal bladewelding and repair techniques.</p> <p>In the area of advanced systems initiated work on gas turbine combustor and nozzle systems for fuel flexible low-NO<sub>x</sub> performance in IGCC applications for designs that are capable of meeting Vision 21 performance requirements.</p> <p>Continued technology base development in the areas of thermal barrier coatings, emission reductions, combustion stability, heat transfer and aerodynamics in turbines for coal derived synthesis gas.</p>	<p>2008.</p> <p>Complete report on combustion performance testing (FY03-50 hrs., FY04-150 hrs.) with variable fuel characteristics such as coal syngas and combustor geometry. This report will help establish the feasibility of trap vortex combustion and the lean pre-mixed combustion conditions for low emissions (&lt; 3 ppm NO<sub>x</sub>) gas turbines. These combustion techniques are critical to gas turbines for low emissions, low-cost and highly efficient coal-based IGCC power plants.</p> <p>Define detailed combustor design requirements for fuel flexible gas turbines. These designs will lead to subscale component testing. Fuel flexible combustors will make possible gas turbines with low emissions for application in low-cost highly efficient coal-based IGCC power plants.</p> <p>Complete assessment and report on process weld conditions and critical parameters on micro structure characterization of single crystal turbine blade failure mechanisms. This information will be publically disseminated for use by single crystal component developers in the power and defense industries.</p>

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		<p>Initiate prototype validation tests (FY04-8,000 hrs., FY05-4,000 hrs.) of a non-destructive evaluation (NDE) technique for predicting failure of thermal barrier and metallic coatings. Tests will be implemented on a W501FD gas turbine. This activity, if successful, will lead to a fully integrated NDE system. Results could be used to reduce gas turbine life cycle costs in advanced power plants.</p> <p>Complete assessment of turbine mechanical faults (bearings, rotor-dynamic, structural, etc.) using vibration signatures with neural-network based fault classifiers. These signatures and fault classifiers will form the basis for a diagnostic monitoring software platform for predicting machine health. Ultimately these results can be used to reduce gas turbine life cycle cost in highly efficient coal-based IGCC power plants.</p> <p>Complete development of a computational software tool-set for designing the next generation of advanced power plants applicable to low-cost highly efficient coal-based IGCC power plants. This software tool will be used to reduce concept development time and cost for advanced power plants.</p> <p>Complete design specifications and cost estimates for balance-of-plant (BOP) components</p>

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
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applicable to sub-MW fuel cell turbine hybrid systems. These BOP components will support the testing of more efficient and advanced hybrid power systems. Hybrid fuel cell turbine power systems support the evolution of highly efficient (75 % for natural gas, 60 % for coal) near zero-emissions MW-scale fuel cell turbine hybrid power plants applicable to Vision 21 power plants.

### Funding Profile

(dollars in thousands)

	FY 2002 Comp. Approp.	FY 2003 Request	FY 2004 Base	FY 2004 Request	FY 2004 Request vs. Base	
					\$ Change	% Change
Central Systems						
Innovations for Existing Plants	\$22,973	\$21,200	\$21,200	\$22,000	\$800	3.8%
Advanced Systems:						
Integrated Gasification						
Combined Cycle . . . . .	41,990	40,650	40,650	51,000	10,350	25.5%
Pressurized Fluidized Bed	10,720	9,100	9,100	0	-9,100	-100.0%
Turbines . . . . .	18,101	14,000	14,000	13,000	-1,000	-7.1%
Subtotal, Advanced Systems . .	70,811	63,750	63,750	64,000	250	0.4%
Total, Central Systems . . . . .	\$93,784	\$84,950	\$84,950	\$86,000	\$1,050	1.2%

### Funding by Site

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	\$Change	%Change
Argonne National Lab (East) . . . . .	\$1,624	\$1,550	\$1,044	\$-506	-32.6%
Brookhaven National Laboratory . . . . .	300	200	200	0	0.0%
Idaho Nat'l Engineering & Environmental Lab . . .	180	180	0	-180	0.0%
Lawrence Berkeley National Lab . . . . .	200	200	200	0	0.0%
Los Alamos National Lab . . . . .	2,171	450	1,364	914	203.1%
National Energy Technology Laboratory . . . . .	11,234	11,852	11,665	-187	-1.6%
Oak Ridge National Lab . . . . .	707	625	215	-410	-65.6%
All Other . . . . .	77,368	69,893	71,312	1,419	2.0%
Total, Central Systems . . . . .	\$93,784	\$84,950	\$86,000	\$1,050	1.2%

## **Site Description**

### **Argonne National Laboratory (East)**

The Argonne National Laboratory (ANL), located in Argonne, Illinois, is a major multi-program laboratory managed and operated for the U.S. Department of Energy (DOE) by the University of Chicago under a performance-based contract. Argonne research for the Fossil Energy Central Systems program supports concepts for various technologies for central systems.

### **Brookhaven National Laboratory**

The Brookhaven National Laboratory (BNL), located on Long Island, New York, conducts research and development in the area of Central Systems to support concepts for various technologies for central systems.

### **Idaho National Engineering and Environmental Laboratory**

The Idaho National Engineering and Environmental Laboratory (INEEL), located outside of Idaho Falls, Idaho, conducts research and development in the area of Central Systems to support concepts for various technologies for central systems.

### **Lawrence Berkeley National Laboratory**

The Lawrence Berkeley National Lab (LBNL), located in Berkeley, California, conducts research and development in the area of Central Systems to support concepts for various technologies for central systems.

### **Los Alamos National Laboratory**

The Los Alamos National Laboratory (LANL), located in Los Alamos, New Mexico, conducts research and development in the area of Central Systems to support concepts for various technologies for central systems.

### **National Energy Technology Laboratory**

The National Energy Technology Laboratory (NETL), located in Morgantown, West Virginia, Pittsburgh, Pennsylvania, and Tulsa, Oklahoma, is a multi-purpose laboratory, owned and operated by the U.S. Department of Energy. NETL conducts and implements science and technology development programs for the Department in energy and energy-related environmental systems. NETL's key functions are to shape, fund, and manage extramural (external) RD&D projects, conduct on-site science and technology research, and support energy policy development and best business practices within the Department.

### **Oak Ridge National Laboratory**

Fossil Energy Research and Development/  
President's Coal Research Initiative/  
Central Systems

**FY 2004 Congressional Budget**

The Oak Ridge National Laboratory (ORNL), located in Oak Ridge, Tennessee, conducts research and development in the area of Central Systems. ORNL is a leader in the development and assessment of advanced materials that are applicable to advanced coal based power generation systems such as Vision 21.

## All Other

The Department's Central Systems program, within the Fossil Energy and Development program, funds research at major performers at non-DOE locations. An example of these performers include the Albany Research Center focusing on various advanced materials and process-related concepts.

### Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
<b>Innovations for Existing Plants</b> .....	<b>22,973</b>	<b>21,200</b>	<b>22,000</b>

The FY 2004 request emphasizes development and field testing of retrofit mercury, NO<sub>x</sub>, particulate matter, and acid gas (SO<sub>3</sub>, HCl, and HF) control technologies, mercury emission, transport, and deposition assessment, technological solutions to emerging energy-water issues such as cooling water requirements, determining PM<sub>2.5</sub> source-receptor relationships as they relate to coal-fired power plant emissions, and environmental characterization of coal-combustion and gasification and other advanced power system byproducts.

■ **Super Clean Systems** ..... 1,450 1,485 1,485

Super Clean Systems research focuses on reducing emissions of primary oxides associated with NO<sub>x</sub> and SO<sub>x</sub> pollution in support of the Clear Skies Initiative. The work will complete Ultra-low NO<sub>x</sub> Burner development, and continue development and pilot-scale testing of novel NO<sub>x</sub> control technology concepts selected under the FY 2002 Broad Based Solicitation and under an FY 2003 targeted solicitation. *Participants include: GTI, Praxair, Wiley, Precision Combustion, TBD.*

FY 2003 and FY 2002 funding continued development of ultra-low NO<sub>x</sub> combustion systems, oxygen-enhanced combustion, Methane-deNO<sub>x</sub> technology, and approaches to controlling NO<sub>x</sub> in cyclone boilers. Initiate dense-phase-reburn research under the FY 2002 Broad Based solicitation. *Participants included: MTI, GTI, Praxair, REI, Alstom, Wiley, Precision Combustion.*

■ **Fine Particulate Control/Air Toxics** ..... 14,338 13,860 13,860

In support of Clear Skies Initiative, continue Phase II field testing of advanced mercury control technologies to achieve 50-70% mercury removal directed at lower rank coals and balance-of-plant issues. Continue bench- and pilot-scale development of novel technology to achieve 90%+ mercury capture. Develop fine particulate and acid gas control and sensor technology selected under FY 2002 solicitation. Continue with more comprehensive modeling assessment of fine particulate and mercury source-receptor relationships. Continue projects selected in FY 2003 to address energy-water issues. *Participants include: ATS, CONSOL, URS, CMU, SRI, Powerspan,*

*Apogee, TVA, UMD, BNL, LBL, RBD.*

FY 2003 and FY 2002 funding continued field testing of two advanced mercury control technologies - sorbent injection and wet-FGD enhancement - to achieve 50-70% mercury control and continued pilot-scale development of six novel mercury control concepts capable of achieving +90% control. Completed pilot-scale development and testing of additives to improve fine particulate capture in ESPs, alkaline injection for controlling acid gas emissions, and an advanced fine particle separation technology. Completed collection of ambient PM<sub>2.5</sub> samples from the upper Ohio River Valley region. Initiated development of on-line continuous SO<sub>3</sub> analyzer and study of in-plume mercury reactions. *Participants included: ATS, LSR, CONSOL, ADA-ES, MTI, Southern Research Institute, CMU, URS, UNDEERC, Apogee, REI, Powerspan, GE-EERC, BNL, ANL, TVA..*

(dollars in thousands)

FY 2002	FY 2003	FY 2004
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■ **In-House** ..... 3,300                      3,663                      3,960

Research and systems analysis is conducted on novel multi-pollutant control, mercury control and characterization, by-product characterization, and water-related issues in support of zero-emissions for Vision 21 and Clear Skies. Provide for customer service and business activities. *Participants include: NETL.*

FY 2003 and FY 2002 funding continued development of mercury control technologies and characterization of mercury emissions in 500 lb/hour combustor and collection of ambient PM<sub>2.5</sub> data from Pittsburgh campus monitoring site. Continued evaluation of mercury and other metal leachates from coal combustion byproducts. *Participants included: NETL.*

■ **Waste Management** ..... 1,450                      1,980                      2,475

Continue assessment of environmental impacts of coal combustion and gasification byproducts and solid residues, focusing on mercury and other trace metals. Conduct joint industry/government R&D activities to maximize recycle use of coal utilization byproducts for various market applications, and facilitate technology transfer. Continue development of byproduct treatment and separation technology selected under FY 2003 Broad Based solicitation. Initiate projects selected under the FY 2003 targeted solicitation to maximize water utilization efficiency with minimal environmental impact. *Participants include: WVU, PPL, UNDEERC.*

FY 2003 and FY 2002 funding continued development of ozone-based unburned carbon separation technology and evaluation of mercury leaching and volatilization from coal byproducts. Initiated assessment of coal drying technology to reduce cooling water makeup requirements. Continued development of high-volume applications for coal byproducts. *Participants included: University of Kentucky, PPL Generation, EPRI, UNDEERC, Lehigh University, CONSOL, WVU.*

(dollars in thousands)

FY 2002	FY 2003	FY 2004
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■ <b>Vision 21</b> .....	2,200	0	0
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No activity. Beginning in FY 2003 and continuing in FY 2004, activities that are focused on efficiency issues are addressed under the Advanced Research Materials program.

FY 2002 research focused on developing advanced materials for enhancing power plant efficiency including supercritical cycles applicable to "Vision 21" goals of developing higher efficiency systems ultimately driving to lower pollution levels (new zero). *Participants included: Siemens-Westinghouse.*

■ <b>Program Support</b> .....	235	212	220
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Fund technical and program management support.

<b>Advanced Systems</b> .....	<b>70,811</b>	<b>63,750</b>	<b>64,000</b>
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Advanced Systems focus on the development of critical enabling technologies and systems for new, cost-competitive plants with increasingly higher efficiencies and inherent ultra-low emissions that support the President's Clear Skies and Global Climate Change initiatives, leading ultimately to near-zero emission Vision 21 power plants compatible with carbon sequestration.

<b>Integrated Gasification Combined Cycle</b> .....	<b>41,990</b>	<b>40,650</b>	<b>51,000</b>
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■ <b>Gasification Systems Technology</b> .....	21,700	20,988	29,700
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**Gasification:** Continue to develop and test the oxygen-blown transport gasifier and associated particulate control devices at the PSDF to reduce cost and improve reliability of gasifier technology. Primary focus at the PSDF will be on oxygen-blown operations to provide options for producing hydrogen and capturing CO<sub>2</sub> and multi-fuel capability to enhance the applicability of the technology. Validate the oxygen-blown transport gasifier CFD model using data generated from the PSDF and the Transport Reactor Development Unit (TRDU) using various coal feedstocks. Utilize the TRDU to pre-screen coal feedstocks, alternative feed systems, and process conditions to provide guidance for testing at the PSDF. Develop advanced materials for refractories and thermocouples to improve refractory performance and improve gasifier reliability. Test prototype refractory bricks in a commercial coal gasifier to demonstrate performance under actual operating conditions, and begin to install a novel high temperature measurement device to demonstrate improved gasifier performance and process control. Continue development of other advanced technologies such as burner flame monitoring, refractory wear monitoring, diffusion coatings, etc. to improve the reliability, availability, and performance of gasifiers. Investigate fundamental pre-competitive technology issues and needs to improve gasification process performance and reliability through the Gasification Technology Research Consortium. **Gas Cleaning/ Conditioning** - Efforts are directed to obtaining near-zero emissions from gasification based systems including construction of a gas cleanup module at PSDF to pave the way for Vision 21 testing of advanced modules for carbon capture and near-zero emission gas cleaning technologies. Development of advanced sorbents for achieving ultra-low sulfur levels of all contaminants at moderate temperatures. Operate the Gas Process Development Unit's (GPDU) using the RT13 sorbent at moderate temperatures in the transport mode to provide design data for scale-up of the technology. Continue validation of the transport desulfurizer CFD model using

data from the GPDU and data generated in a pilot-scale test facility integrated with a coal gasifier. Develop the novel Selective Catalytic Oxidation of Hydrogen Sulfide (SCOHS) technology and begin bench-scale evaluations for proof-of-concept testing of the technology to demonstrate ultra-low sulfur emissions at reduced cleanup costs. *Participants include: SCS, NETL, UNDEERC, Fluent, RTI, Albany, ChevronTexaco, VPI, FluoreScience, IET, GTI, GEC, MSE, SRI, Comb Spec.*

In FY 2003, the transport gasifier and associated particulate control devices will be further developed under oxygen-blown conditions at the PDSF. The TRDU will pre-screen coal feedstocks and process conditions for testing at the PDSF. Bituminous coals will be processed at the PDSF to determine the applicability of the gasifier for high rank coals. A new dry coal feed system will be evaluated to reduce cost and improve performance over conventional lock hopper feed systems. Performance of new refractory bricks under simulated gasifier conditions will be evaluated, and if successful, bricks will be installed in high wear areas of Eastman Chemicals' coal gasifier in Kingsport, TN. Development of technologies to improve the reliability, availability, and performance of gasifiers will continue with testing of one high-temperature measurement device on the TECO IGCC gasifier. The Gas Process Development Facility (GPDU) will be operated using the EXSO3 sorbent developed previously for hot gas desulfurization and will transition to lower temperature operations to support the scale-up of the RT13 sorbent. Development of the Selective Catalytic Oxidation of Hydrogen Sulfide (SCOHS) process will continue to confirm process performance at the laboratory scale in preparation for future bench-scale testing.

In FY 2002, continued development of the transport gasifier which provided the basis for the proposal for a demonstration facility in the CCPI solicitation. Preliminary modifications were completed to permit the first demonstration of oxygen-blown operation of the transport gasifier at the PDSF. The TRDU provided guidance on the design and operation of the gasifier based on screening studies. A new refractory material was developed and patented that has potential for increasing refractory life by five times that of today's materials. Full-size bricks were produced by a commercial refractory manufacturer. Installation of one high-temperature measurement device was initiated on the TECO IGCC gasifier, and a second device is beginning scale-up for possible testing at the Wabash River IGCC plant and/or Eastman's Kingsport, TN, gasifier to improve process control and reliability. A sulfur sorbent was successfully produced with appropriate attrition resistance for use in a transport reactor while simultaneously achieving sulfur levels of 1 ppm. Shakedown of the GPDU progressed well and is ready for initial sorbent operation.

*Participants include: SCS, NETL, UNDEERC, Fluent, RTI, Albany, ChevronTexaco, VPI, FluoreScience, IET, GTI, GEC, MSE, SRI, Comb Spec.*

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
■ <b>Systems Analysis/Product Integration</b> .....	3,652	2,921	3,960

Complete engineering designs of Early Entrance Coproduction Plants for clean fuels like hydrogen and high efficiency power productions as pre-Vision 21 concepts. Continue systems analyses for research guidance and product outreach activities. Update the worldwide gasification database. Establish size of standardized IGCC plants from market analysis and begin design of modular unit to reduce plant cost, shorten plant startup schedule, and improve system reliability. *Participants include: NETL, CTC, E2S, Mitretek, SFA, Pacific, Texaco, Parsons, WMPI, GE, KBR, Praxair.*

In FY 2003, work is continuing on risk mitigation for the Early Entrance Co-production Plants and the results were used to update the preliminary process design and analysis. The co-production design optimization study is being completed and a comprehensive report will be issued. Systems studies are being conducted to evaluate the cost and performance improvements of all technologies being developed and will be used to develop a comprehensive program roadmap. The biannual update of the world-wide gasification database was performed.

In FY 2002, continued development of engineering analysis and the conduct of risk reduction R&D for the Early Entrance Co-production Plant. Progress on the WMPI project led to a proposal in the CCPI solicitation. Task 1 of the design optimization study was completed and was used as the basis of the Nordic Energy proposal in the CCPI solicitation. A comprehensive report was issued describing the industry perspective on future markets and technology needs for gasification.

*Participants included: NETL, CTC, E2S, Mitretek, SFA Pacific, ChevronTexaco, Parsons, WMPI, GE, KBR, Praxair, Global Energy, Dow Corning, Dow Chemical, Siemens Westinghouse, Methanex, Nexant.*

■ <b>Vision 21</b> .....	16,208	16,334	16,830
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To achieve the Vision 21 program goals, develop novel technologies that lead to ultra-high efficiencies, near-zero emissions, carbon capture for sequestration and the production of hydrogen for ultra-clean fuels and powers. Scale-up and test ceramic membrane modules for advanced air separation at the 1-5 ton/day scale to reduce the cost of oxygen and pave the way for the economical capture of CO<sub>2</sub>. Begin initial planning of 50 ton/day membrane modules for integration with a gasifier and gas turbine. Investigate improved membrane materials, fabrication techniques, and module design for H<sub>2</sub>/CO<sub>2</sub> separations to address capture of CO<sub>2</sub> and for producing low-cost hydrogen from coal. Conduct life testing of advanced ceramic hydrogen membranes and develop conceptual process designs. Construct a polymer hydrogen membrane module for integrated testing with a pilot-scale coal gasifier to address performance under actual process conditions. Construct skid-mounted unit for the development of the low temperature hydrate technology to demonstrate effective carbon management by separating hydrogen and carbon dioxide and begin preliminary site evaluation for integration with a gasifier. Investigate advanced gas cleaning technologies to meet near-zero emission requirements in response to the

Clean Skies Initiative. Begin testing of an advanced sulfur cleanup technology integrated with a pilot-scale coal gasifier to evaluate process performance under realistic conditions. Construct skid-mounted process units for mercury, ammonia, and chloride control for possible integrated testing with a pilot-scale coal gasifier. Complete conceptual design and economic analysis of a novel coal gasification concept for producing hydrogen and sequestration-ready CO<sub>2</sub> that has potential for cost reductions over conventional approaches. *Participants include: APCI, Praxair, ANL, Concepts NREC, Ceramatec, Texaco, PSU, Penn, Bechtel, LANL, RTI, Medal, Protech, IGT, Siemens-Westinghouse, NETL, REI, GEERC, INT, Eltron, Praxair, Coors, INEEL, Sud Chemie, SRI, ORNL, McDermott, KBR.*

In FY 2003, negotiations with ChevronTexaco will be completed on the testing of the RT13 advanced transport sorbent integrated with their pilot-scale coal gasifier. The transport desulfurizer module will be designed, constructed, and installed in preparation for a 500-1000 hour test run. Investigation of ammonia, chloride, and mercury removal approaches will focus on obtaining sufficient performance and process data to design modules for integration with a pilot-scale coal gasifier. Laboratory scale testing of advanced ceramic air separation membranes will be completed to provide process design data for the 1-5 TPD engineering-scale unit and to finalize the design of the commercial-scale modules. Preliminary investigations of potential sites for integrated testing of the membrane modules with a gasifier and gas turbine will commence. Development of ceramic-based H<sub>2</sub>/CO<sub>2</sub> membranes will focus on further increases in H<sub>2</sub> flux to achieve commercially relevant flux targets. Development of the polymer-based membrane for H<sub>2</sub>/CO<sub>2</sub> separation will focus on further testing of the membrane to improve CO<sub>2</sub> flux and to obtain engineering data for the design of a module for integration with a pilot-scale coal gasifier. Engineering data will be obtained from a laboratory-scale flow unit for the CO<sub>2</sub> hydrate process to establish the design basis for a skid-mounted unit. Initial study on the feasibility of a novel gasification concept for producing hydrogen and sequestration-ready CO<sub>2</sub> will be completed.

In FY 2002, continued the development of advanced air separation membranes, with both projects focusing on scale-up of the technologies for 1-5 TPD oxygen production level. Full-scale membranes that achieve the commercial target flux were successfully produced. The advanced RT13 sulfur sorbent performed successfully using a simulated coal-based synthesis gas, and negotiations with ChevronTexaco were initiated for integrated testing with a pilot-scale coal gasifier. Advanced ceramic membranes for H<sub>2</sub>/CO<sub>2</sub> separation achieved an order of magnitude increase in flux while a polymer-based membrane has attracted the interest of ChevronTexaco. Scale-up and testing of a latter membrane are part of the negotiations with ChevronTexaco. The formation of CO<sub>2</sub> hydrates in a continuous flow unit was successfully demonstrated and preliminary economic analyses show a substantial improvement in cost and efficiency over conventional technologies.

*Participants included: APCI, Praxair, ANL, Concepts NREC, Ceramatec, ChevronTexaco, PSU, Penn, Bechtel, LANL, RTI, Medal, Protech, IGT, Siemens-Westinghouse, NETL, REI, GEERC, INT, Eltron, Coors, INEEL, Sud Chemie, SRI, ORNL, McDermott, KBR.*

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
■ <b>Program Support</b> .....	430	407	510
Fund technical and program management support.			
<b>Pressurized Fluidized Bed</b> .....	<b>10,720</b>	<b>9,100</b>	<b>0</b>
■ <b>Gas Stream Cleanup</b> .....	4,090	5,445	0
This activity concluded and folded into gasification activity.			
FY 2003 and FY 2002 funding continued development of hot gas filters, a number of hot gas filter materials, certain designs validated and a broad fail safe development initiated at the PSDF. Pilot plant testing of partial gasification Vision 21 modules was undertaken and the first tests of various coal and biomass were completed, including one run oxygen in place of air. <i>Participants included: Southern Co.</i>			
■ <b>Hybrid Combustion</b> .....	3,110	3,069	0
This activity concluded and folded into gasification activity.			
FY 2003 and FY 2002 funding continued development of Vision 21 hybrid system enhancements and design optimization studies were undertaken as well as development of novel hybrid concepts. Two hybrid site specific repowering studies were completed and accepted by participating utilities. <i>Participants included: NETL, Alstom</i>			
■ <b>Vision 21</b> .....	3,410	495	0
This activity concluded and folded into gasification activity.			
In FY 2003 and FY 2002, Vision 21 combustion kinetic studies and testing were initiated and development of viable codes were undertaken. Investigations were begun into the feasibility of enabling Vision 21 combustion technologies such as chemical looping. <i>Participates included: Fluent.</i>			
■ <b>Program Support</b> .....	110	91	0
Fund technical and program management support.			
<b>Turbines</b> .....	<b>18,101</b>	<b>14,000</b>	<b>13,000</b>
■ <b>Vision 21</b> .....	2,542	0	0
This activity is continued in the High Efficiency Engines and Turbines (HEET) subprogram described below.			
In FY 2003, this activity is continued in the High Efficiency Engines and Turbines (HEET) subprogram described below. In FY 2002, preliminary studies were completed that identified			

advance turbine hybrid systems for application to coal-based Vision 21 power systems. Sub-MW hybrid power systems were operated with outstanding thermal efficiencies. *Participants included:*

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
■ <b>High Efficiency Engines and Turbines (HEET)</b> . .	15,374	13,860	12,870
<p>In support of developing power modules for zero-emission Vision 21 plants, conduct R&amp;D in four program areas to include: 1) simple and combined cycle development, 2) advanced systems analysis, 3) hybrid cycles, and 4) technology base development. Simple and combined cycle development will pursue the adaptation of existing and advanced gas turbines for application to coal derived synthesis gas as well as ways of reducing the life cycle cost of these machines when operated on coal derived gas. Advanced system analysis will assess revolutionary concepts for application and integration into Vision 21 power systems. The hybrid cycles area will resolve component, integration, control and operational issues for fuel-flexible and robust performance in Vision 21 power plants. The technology base area will provide the basic underpinning for the program areas resolving materials, heat transfer, aerodynamics and combustion technical issues as new machines and systems are applied to coal derived gases. <i>Participants include: GE, SWPC, EPRI, NETL, U. of CA-Irvine, CFD Research, ORNL, ANL.</i></p> <p>In FY 2003, the HEET program will complete studies to assess ATS and other machines for operation on coal syngas, as well as ATS machines in coal and natural gas based integrated hybrid power modules, complete demonstration of low-emission steam generator, demonstrate an integrated sensor suite for real-time monitoring of an advanced turbine's operational performance, and demonstrate in-situ single crystal blade welding and repair techniques.</p> <p>In FY 2002, the HEET program evaluated techniques for low NO<sub>x</sub> combustion through trapped vortex combustion and catalytic combustion. Preliminary studies were completed that identified advance turbine hybrid systems for application to coal-based Vision 21 power systems. Sub-MW hybrid power systems were operated with outstanding (53 percent as compared with current technologies between 20 and 40 percent) thermal efficiencies. Progress was made towards reducing life-cycle costs through condition monitoring and materials evaluations.</p> <p><i>Participants included: GE, SWPC, Solar, EPRI, NETL, SCIES, U. of CA-Irvine, CFD Research, ORNL, ANL.</i></p>			
■ <b>Program Support</b> . . . . .	185	140	130
Fund technical and program management support.			
<b>Total, Central Systems</b> . . . . .	<b>93,784</b>	<b>84,950</b>	<b>86,000</b>

## Explanation of Funding Changes

FY 2004 vs. FY 2003 (\$000)
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### Innovations for Existing Plants

■ Increase in In-House research due to additional research on advanced emission control technology .....	297
■ Increase in Waste Management due to additional research into solids by-products utilization .....	495
■ Program Support .....	8

### Advanced Systems

#### Integrated Gasification Combined Cycle (IGCC)

■ Increase in Gasification Systems Technology due to transfer of activity from Pressurized Fluidized Bed .....	8,712
■ Increase in Systems Analysis/Production Integration due to additional analyses of new concepts including gasification hybrids .....	1,039
■ Increase in Vision 21 due to transfer of activity from Pressurized Fluidized Bed . . .	496
■ Increase in Program Support due to additional studies .....	103

#### Pressurized Fluidized Bed

■ Decrease in Gas Stream Cleanup due to discontinuation of activity and transfer to ICGG .....	-5,445
■ Decrease in Hybrid Combustion due to discontinuation of activity and transfer to IGCC .....	-3,069
■ Decrease in Vision 21 due to discontinuation of activity and transfer to IGCC . . . .	-495
■ Program Support in this area eliminated .....	-91

#### Turbines

■ Decrease in High Efficiency Engines and Turbines (HEET) due to reduced effort in combustion NO <sub>x</sub> control .....	-990
■ Program Support .....	-10

<b>Total Funding Change .....</b>	<b>1,050</b>
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